İSTANBUL UNIVERSITY CERRAHPAŞA

HAYEF: Journal of Education, 19(2); 122-129

DOI: 10.54614/hayef.2022.21064

Received: December 14, 2021
Accepted: February 19, 2022

HAYEF: Journal of Education

RESEARCH ARTICLE

Project-Based Learning on Socio-scientific Issues in Environmental Education

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Abstract

In this study, the development process of project-based learning activities based on socio-scientific issues in environmental education in the teacher-training program is presented. At the beginning of the development process, the learning objectives, the content boundaries, and socio-scientific issues were determined. The project-based learning activities were designed to contain the concepts of ecological balance/ecosystem, ecological problems, matter cycle, carbon and ecological footprint, endemic and endangered species, reasons, reducing pollutions (e.g., water, air, land, nuclear, and noise pollution), and recycling. Each activity begins with videos or newspaper clippings including socio-scientific issues causing an environmental problem. Prospective teachers are required to plan and conduct their projects considering project-based learning steps to solve this environmental problem. An assessment rubric is also presented for evaluation of the project-based learning process and prospective teachers' project report. Project-based learning activities based on the socio-scientific issue in the environmental education in this study are of value and practical in the teacher training classrooms, especially in science and elementary education programs.

Keywords: Environmental education, project-based learning, socio-scientific issue

Introduction

In the developing and changing world, the unlimited consumption desire of people causes the unplanned use of natural resources. The fact that the natural resources that make up the environment are not used correctly brings out environmental problems. The main problems are climate change, global warming, extinction of species, several pollutions, such as land, air, and water, improper disposal of waste, decrease in agricultural areas, water scarcity, and deforestation. Although various legal and technological measures have been taken to deal with environmental problems, environmental problems are not a problem that can be solved only with technology or laws (Erten, 2003). People are self-centered for protecting the environment, and they need to realize that the protection of the environment is their duty (Zulhaimi et al., 2019). It is possible to raise this awareness with environmental education.

Training of people who have positive and permanent behavioral changes, participating actively in the solution of environmental problems (Şimşekli, 2004), making appropriate decisions regarding the environment, and giving and showing the right behaviors (Hart, 2007) are aimed with environmental education. However, according to the Tbilisi Declaration, "Some gaps that need to be filled still exist in education systems for environmental education to achieve its goals" (as cited in Ünal & Dımışkı, 1999). For this reason, learning environments based on active learning approaches, especially at the teacher training level, are of great importance for effective environmental education. One of these learning approaches is the project-based learning approach.

The work done by students using their high-level thinking skills to create an original product is called a project (Ün Açıkgöz, 2014). With the projects, the students research the subject of the project deeply and present the information obtained from the project through various methods. According to their purpose and application, projects can be examined in different classes. Projects can be classified as *building or machine projects* that deal with the creation and operation of a tool, model, and prototype, *experimental/research/measurement projects* in which the effect of one or more independent variables on the dependent variable are investigated, and *research and exploration projects* in which a subject is investigated in depth using various sources (Korkmaz, 2002).

Project-based learning is an active process in which the problem is defined, hypotheses are posed and tested, and data is collected and interpreted using the scientific method (Wiese, 2002). This method provides students to work in small groups in coordination with other students (Seloni, 2005) and is an effective method in which interdisciplinary problems can be solved (Dede & Yaman, 2003). Due to the features of project-based learning, it is one of the appropriate approaches for effective environmental education and research. Some project-based learning studies investigate pre-service teachers' ecological intelligence (Ramadhan, 2021), environmental knowledge and attitudes toward the environment (Genç, 2015; Yavuz, 2006), knowledge levels on global warming, critical thinking skills (Erdoğan, 2007), understanding of the environmental issue and their attitudes toward the environment (Koçak, 2008), and is designed a project for

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Cite this article as: Acar Şeşen, B., & Mutlu, A. (2022). Project-based learning on socio-scientific issues in environmental education. *HAYEF: Journal of Education.*, 19(2), 122-129.

water pollution (Rosenfeld & Ben-Hur, 2000). The studies showed that project-based learning has positive outcomes in environmental education.

Socio-scientific issues are generally expressed as issues that deal with ethical, moral, or legal dilemmas, for which there is no definite answer, and which are formed by the interaction of science and technology (Nielsen, 2012). They generally include open-ended questions, and in this respect, they contain uncertainty and confusion (Simonneaux, 2011). Environmental issues, by their nature, include socio-scientific issues, and this situation has necessitated a more intensive study about socio-scientific issues in environmental education. In the literature, it has been determined that there are studies on environmental issues such as global warming and greenhouse effect (Klosterman & Sadler, 2010; Lester et al., 2006; Topçu, 2008) and nuclear energy/power plants (Özdemir, 2014; Sevim & Ayvacı, 2020).

Environmental education at the teacher training level is of major importance to train conscious and sensitive teachers for environmental problems. Effective environmental education is possible with well-planned learning activities. This study aimed to develop project-based learning activities based on the socio-scientific issues in environmental education at the teacher training level.

Method

In this study, project-based learning activities based on socio-scientific environmental issues are presented. This section describes the development process in detail.

Development Process of the Project-Based Learning Activities Based on Socio-scientific Environmental Issues

Reviewing scientific research is important to design the learning process. Therefore, at the beginning of the process, research on project-based learning and socio-scientific issues and activities in environmental education were reviewed. After learning objectives and content boundaries were determined, socio-scientific environmental issues were identified. The objectives for activities were identified as:

- Prospective teachers will be able to learn basic ecological concepts.
- Prospective teachers will be able to explain ecological balance.
- Prospective teachers will be able to learn the matter cycle and its importance for livings.
- Prospective teachers will be able to learn about endemic and endangered species and to protect them.
- Prospective teachers will be able to learn the reasons and results of environmental pollutions and to propose reducing ways of them.
- Prospective teachers will be able to learn the importance of recycling and implement recycling activities.
- Prospective teachers will be able to propose a solution for different environmental problems.

To achieve these learning objectives, the following contents were identified: ecological balance/ecosystem, ecological problems, matter cycle, carbon and ecological footprint, endemic and endangered species, reasons and reducing ways of pollutions (water, air, land, nuclear, and noise pollution), and recycling. Totally, 13 project-based learning activities based on socio-scientific environmental issues were developed. The information about each activity can be seen in Table 1.

Each activity begins with videos or newspaper clippings including socio-scientific issues causing an environmental problem. Prospective teachers are steered to discuss these socio-scientific environmental issues and to share their opinion with their groupmates (it is suggested that these activities are conducted with 13 cooperative groups). After the discussions, an environmental problem about the socio-scientific issue is given to prospective teachers, and they are supposed to plan and conduct a project following steps of project-based learning for solving this environmental problem. In the context of these projects, prospective teachers can do experiments, design a prototype, conduct an interview, or make an extensive investigation using newspaper archives and online sources. In the last step of the activity, the results of the projects are presented using posters, computer presentations such as PowerPoint, Prezi, and so on, or demonstration of their prototypes or/and experiments is done to the whole class. In addition to these, a weekly progress report is required from onset to completion of the project.

Thirteen worksheets were also designed for each project-based learning activity. These worksheets were designed considering the project-based learning approach's steps. According to these steps, each worksheet begun with an URL for a video or news and their screenshots. Hence, socio-scientific issues were presented in these ways. Some explanations were also given about these socio-scientific issues in the worksheets. While carrying out the project, the following steps are considered in the worksheet:

- Define the problem situation together with your groupmates.
- What is your project for solving your problem?
- To accomplish your project, make your task distribution and work plan in your group.
- Explain what you did and the information you obtained from your project.
- Prepare a report including your project's results.
- Prepare a poster, demonstration, and/or ppt presentation to present your report.
- Present it to your friends.

After all the worksheets and activities were reviewed by three science educators and one science teacher. In addition to these, it was piloted by five fourth-year prospective science teachers in terms of the understandability and applicability of the projects. In the light of all comments, the final versions of the worksheets and activities were prepared.

An Experimental Project: How Is This Rain?

An example activity entitled "How is this rain?" aimed to provide comprehension and awareness of ecological problems. For this purpose, industrialization was assigned as a socio-scientific issue for starting the activity. This socio-scientific issue was presented in the worksheet with a newspaper clipping. A screenshot of a part of this newspaper clipping was given in Figure 1.

Industrialization is important for production. In this way, a significant part of the products that we need is produced and the quality of human life increases. It also offers job opportunities to many people. On the other hand, if the factories do not take the necessary precautions to protect the environment, they cause irreversible damage to the environment. Unfortunately, these precautions are not taken at a sufficient level today. Some factories are dangerous because of the production of hazardous material or chemicals. Moreover, some of them are also at risk of accidents and these accidents affect the environment and human life negatively like the presented news. The sulfur-production facility in the news was damaged and there was a concern about the formation of acid rains because of the toxic gases released.

Table 1.
Project-Based Learning Activities Based on the Socio-scientific Environmental Issues

Name of the Activity	Related Environmental Issue	Socio-scientific Issue	Socio-scientific Dilemma	Project Issue
Journey of pesticides	Ecological balance/ ecosystem	Using pesticides	Reasons for using the pesticide vs effect of pesticide on the environment	Effect of the pesticides on ecological balance and ecosystem
Oops, the temperature is rising!	Ecological problems	Human activities causing global warming	The necessity of some human activities causing global warming vs the effect of these activities on the environment	Effect of global warming on the world and/or reducing ways of its effects
For more and more fruits	Matter cycle	Chemical fertilizers	Reasons for using the chemical fertilizers vs. effect of them on the environment	Effect of chemical fertilization on matter cycles
My footprint-1	Carbon and ecological footprint	Human activities causing to increase carbon footprint	The necessity of some human activities causing to increase carbon footprint vs effect of these activities on the environment	Ways for reducing the carbon footprint
We are no more	Endemic and endangered species	Hunting	Hunting for nutrition vs effect of hunting on animal life, population, and ecological balance	Protecting endemic and endangered species
You are burning us	Land pollution	Burning stubble	Reasons for burning stubble vs. effect of burning stubble on land pollution	Effect of burning stubble on land pollution or an alternative environmentally friendly methods instead of burning stubble
Cyanide in the Ergene River	Water pollution	Industrialization	Opportunities of industrialization vs. effect of factories on water pollution	Reducing water pollution and/or creating the biologically cleaning methods for polluted water
I cannot breathe	Air pollution	Industrialization, using vehicles, and fossil fuels	The necessity of industrialization, using vehicles, and fossil fuels vs. effects of air pollution	Environmentally friendly ways to reduce air pollution
Big energy in new Chernobyl	Nuclear pollution	Nuclear power plants	Opportunities of nuclear energy vs. risks of nuclear power plants	Alternative environmentally friendly methods instead of nuclear power
Waste is gold	Recycling	Consumption activities	Consumption vs. depletion of natural resources	Recycling of waste
This sound is making me sick	Noise pollution	Noise sources in daily life	The necessity of activities causing noise vs. the need for silence	Ways to reduce/control noise pollution
My footprint-2	Carbon and ecological footprint	Human activities causing to increase in ecological footprint	The necessity of some human activities causing to increase in ecological footprint vs. effect of these activities on the environment	Ways for identifying and reducing the ecological footprint
How is this rain?	Ecological problems	Industrialization	Opportunities of industrialization vs. accident risk in a factory	The effect of acid rains and ways to reduce them

Figure 1.
Screenshot of a Part of a Newspaper Clipping about Acid Rain News. Retrieved from https://www.aa.com.tr/tr/turkiye/meteorolojiden-asit-yagmuru-aciklamasi/673555

In the first step of this activity, prospective teachers discuss the dilemma of industrialization. The instructor asks questions to the guide to provide effective discussions. After the discussion, planning a project about the effects of acid rains and the ways to reduce the effects and writing the project plan in the worksheet are requested from the prospective teachers.

In the second step of the activity, prospective teachers make a task distribution and prepare a project plan. Worksheets will be a guide to them to accomplish this step. In this step, prospective teachers are expected to develop their own projects. As an expected project example, an experimental project can accomplish this activity. Prospective teachers can compare the effects of acid rains on a land ecosystem using steps of the scientific method.

Materials for this experiment are the following:

- pH strips,
- four Erlenmeyer flasks,
- same amount and identical land,
- identical lettuce seeds
- four rubber bungs,
- L-glass pipes,
- *Elodea* plant,
- water,
- 100 mL H_2SO_4,
- copper wire,
- laboratory hose, and
- melted candle,

First, moist soil from the garden is taken to prepare two identical land ecosystems and the pH of the soil is measured. An equal amount of soil is put in two Erlenmeyer flasks. An equal amount of lettuce seeds is sowed into the soil (Figure 2).

Some water is put in Erlenmeyer flasks to prepare a water ecosystem. Elodea plants are also used in this ecosystem to provide oxygen to the land ecosystems (Figure 3).

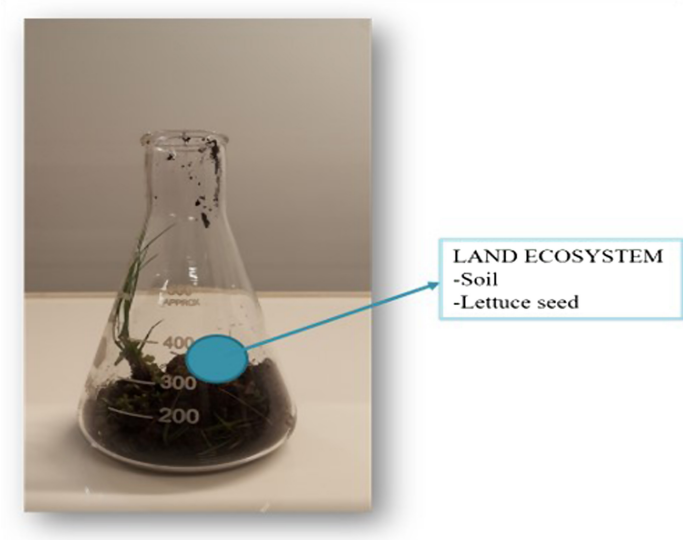

Figure 2.
A Land Ecosystem.

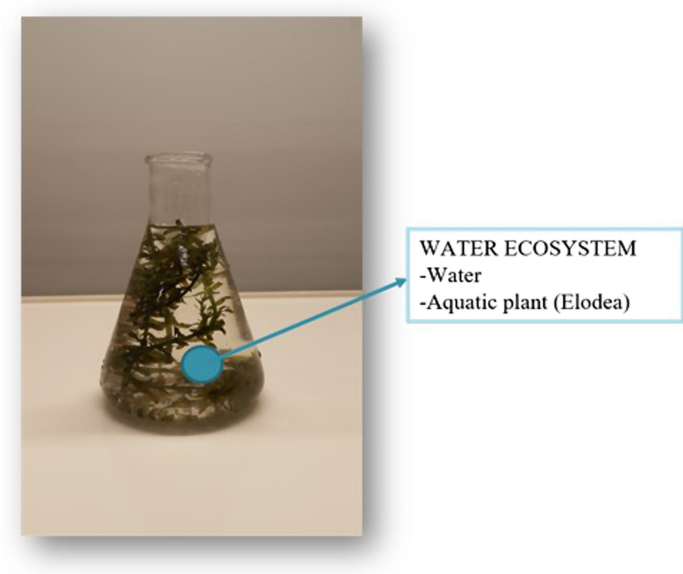

Figure 3.
A Water Ecosystem.

Lastly, some H_2SO_4 and copper wire are put in Erlenmeyer flasks to prepare an acid rain system (Figure 4). H_2SO_4 and copper wire will react and SO_2 will be produced with the following reaction:

$$2H_2SO_{4\,(l)} + Cu_{(s)}\ CuSO_{4\,(aq)} + SO_{2\,(g)} + 2H_2O_{(l)}$$

Four Erlenmeyer flasks are connected with L-glass pipes and laboratory hoses (Figure 5). To prevent the airflow of the Erlenmeyer flasks with the external environment, the cover of pipes in the hole of the rubber bungs are closed with melted candles.

The system is observed for 2 weeks. The development of lettuce seeds and the formation of lettuce shoots in the Land ecosystem-I and Land ecosystem-II are compared. The difference in growing levels of the lettuce shoots will show the effect of acid rain on the land ecosystem.

After the accomplishment of the experiment, prospective teachers are required to prepare a report for the project. The report should include the information gained with the project and their project results. Lastly, preparing a presentation (posters, computer presentations, or demonstration of their prototypes or/and experiments) to present their project report to the whole class was requested.

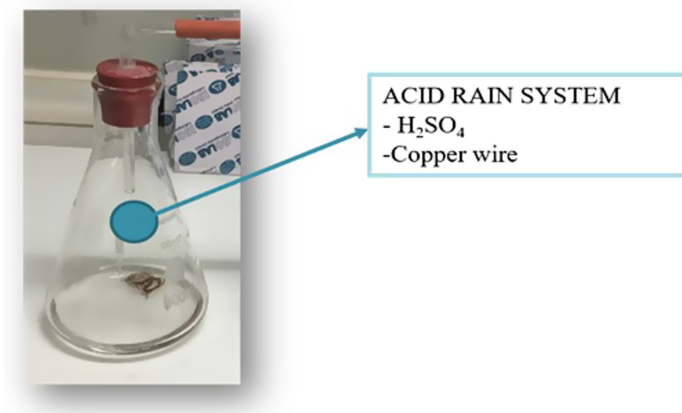

Figure 4.
An Acid Rain System.

A Building Project: My Footprint-I

This activity is related to the carbon footprint. The socio-scientific issue for this activity was assigned since some human activities causes an increase in carbon footprint. Some news about carbon footprint were presented in the worksheets to introduce the socio-scientific issue. A sample of this news was shown in Figure 6.

After presenting the news, a reading part is given to present the dilemma about human activities causing to increase in carbon footprint. Humans carry out some vital activities to live. The main ones are shelter, nutrition, transportation, and industrialization. To live, people have to perform these activities. On the other hand, humans use natural resources while carrying out these activities. The continuation of human activities in their current form shows that the world will not be enough for everyone in the future.

After dealing with the news and reading part, prospective teachers discuss the dilemma under the guidance of the instructor. Then, they are required to conduct a project about the ways for reducing the carbon footprint under the light of these discussions. In the next step of the activity, prospective teachers prepare a project plan after their task distributions. In this step of the activity, prospective teachers are required to develop their own projects. As an expected project example, a building project can accomplish for this activity and prospective teachers can design an ecological house prototype (Figure 7).

Carbon emissions and carbon footprints are minimal in this ecological house. Electricity is completely produced by renewable energy sources such as wind turbines and solar panels. Energy-saving bulbs are used. This house is insulated with eco-friendly materials. It does not contain carcinogenic or substances that are harmful to nature. Zero waste implementations are conducted in this house. Waste is minimal. The materials used in the house are completely recyclable. There are recycling bins for recycling the wastes. Plenty of trees has been planted for the absorption of carbon dioxide.

After designing the prototype of the ecological house, a project is reported including the theoretical framework and result of the project. Lastly, a prototype of the ecological house is introduced to the whole class through a computer presentation or a poster.

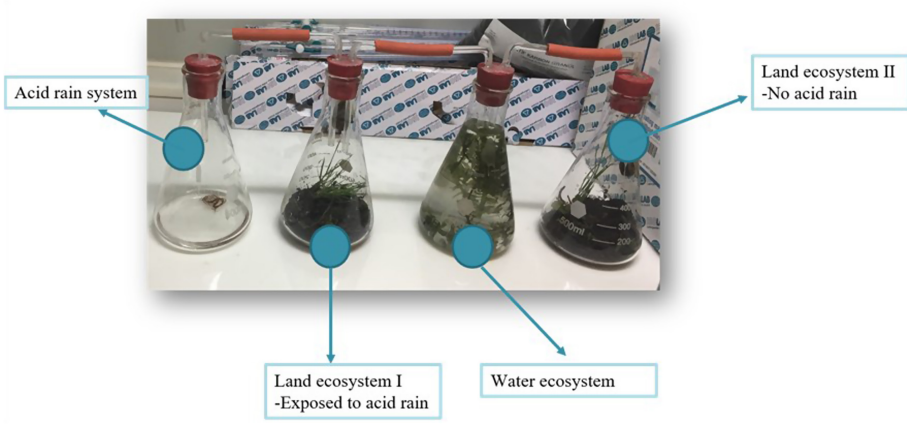

Figure 5.
A System to Compare Acid Rain on Land Ecosystem.


Milliyet
Eskişehir
Hedef; 'Yeşil Ambulans Filosu'
Haberler > Yerel Haberler > Eskişehir Haber > Hedef; 'Yeşil Ambulans Filosu' Ha...
Google News
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Hedef; 'Yeşil Ambulans Filosu'
Eskişehir İl Sağlık Müdürü Dr. Ali Mumcu, kentte bulunan mevcut 112 ambulans faaliyetlerinden kaynaklanan "Karbon Ayak İzi Envanterinin" hesaplanması ve üretilen karbon ayak izinin dengelenmesi için gerekli çalışmaların yapıldığını, amaçlarının "hedef yeşil ambulans filosu" olduğunu belirtti.
22.09.2016 - 11:03 | Son Güncellenme: 22.09.2016 - 11:53

Figure 6.
Screenshot of a Part of a Newspaper Clipping about Carbon Footprint News. Retrieved from https://www.milliyet.com.tr/yerel-haberler/eskisehir/hedef-yesil-ambulans-filosu-11562270

Figure 7.
An Ecological House Prototypes.

Assessment of the Projects

Prospective teachers were required to prepare a project report after the project and progress reports from onset to completion of the project every week. An assessment rubric was also developed in this study for evaluation of prospective teachers' these project reports. The assessment rubric has three parts: Evaluation of the report, evaluation of the project and evaluation of the using scientific process skills. Each part includes some criteria (Table 2).

Table 2.
Parts of Assessment Rubric and Their Criteria

Parts of the Assessment Rubric	Criteria	Range of the Scores
Evaluation of the report	Use of scientific language	4-0
	Understanding of scientific concepts	4-0
	Presentation of the report	3-0
	Delivery of the report	4-0
	Using of resources	4-0
	Using supplementary materials	4-0
	Language and layout of the report	3-0
Evaluation of the project	The originality of the project	4-0
	Realizability of the project	3-0
	Presentation of a project plan-B	4-0
	The theoretical framework of the project	4-0
	Implementation steps of the project	4-0
	Task distributions in the project	2-0
Evaluation of the using scientific process skills	Using scientific process skills	4-0
	Defining the problem	3-0
	Pose a hypothesis	3-0
	Designing research	3-0
	Doing an experiment	3-0
	Saving data	3-0
	Interpreting data	3-0

Each criterion was scored with a numeric value ranging between 4-0, 3-0 and 2-0 according to the nature of the criteria. This scoring provides quantitative data of the assessment. Improving the progress reports can be determined and project reports of each group can be compared with each other through these quantitative data. In addition to these, there is a comment/explanation part for each criterion in the rubric and the reports can be qualitatively analysed in this way. The rubric was reviewed by three science educators and one measurement and evaluation expert. It was also piloted by five fourth-year prospective science teachers in terms of the understandability of the rubric.

Discussion and Conclusion

In this century, there are great developments both scientifically and technologically. On the other hand, environmental problems that arise in parallel with modernization are being struggled. To be successful in this manner, people need to raise awareness of environmental problems. Education is a powerful tool that enables people to understand our depleted resources and effective methods to protect the environment (Zulhaimi et al., 2019). At this point, environmental education becomes more important to cope with environmental problems and to leave a liveable world for future generations. Well-planned activities to raise awareness are a major need for effective environmental education. For this reason, in the present study, 13 project-based environmental activities based on the socio-scientific issue in the teacher training level that has a high potential to gain knowledge and environmental awareness to prospective teachers were developed.

Activities in this study are based on project-based learning, and prospective teachers consider steps of the project-based learning. While accomplishing these activities, prospective teachers define a problem, pose a solution for this problem, and test this solution by conducting a project. Therefore, while they are solving an environmental problem, they work using a scientific method like a scientist. According to the research results of Genç (2015), project-based learning is an effective approach for identifying the environmental problem and it makes prospective teachers more active in the learning process. In accordance, it is expected that project-based environmental activities developed in this study will be effective in environmental education. Moreover, as a different and original point of this study from the other project-based studies, socio-scientific issues were used as the relevant contexts to conduct the projects. Prospective teachers confront an environmental problem including a dilemma, based on presented socio-scientific issues they negotiate and decide upon to solve this problem by conducting a project. Therefore, socio-scientific issues enriched project-based environmental activities.

It is of great importance to train conscious and aware teachers about environmental problems because pre-service teachers, who are today's students, will teach environmental problems and their solutions in their classrooms in the future. Therefore, the environmental awareness of future generations depends on their teachers. Because the quality of teachers' teaching activities directly affects their students (Creemers et al., 2013). Increasing the environmental awareness of prospective teachers is important because they provide their students who will take an active role in solving environmental problems in the future to gain this awareness. For this reason, effective environmental education supported by well-designed activities like were presented in this study is a great need in teacher training level.

Extension and Suggestions for Future Implications

Project-based environmental activities based on socio-scientific issues developed in this study can be used in all teacher training programs, which have environmental education, especially science and elementary education program. These activities can be conducted online as well in the classroom. Especially during the COVID-19 pandemic, online learning environments and using educational technology have gained importance. Activities in this study are suitable to conduct for distance learning. Prospective teachers can discuss socio-scientific issues given to them, plan their projects, and present their project reports using online education platforms.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – B.A.Ş., A.M.; Design – B.A.Ş., A.M.; Supervision – B.A.Ş., A.M.; Materials – B.A.Ş., A.M.; Analysis and/or Interpretation – B.A.Ş., A.M.; Literature Review – B.A.Ş., A.M.; Writing – B.A.Ş., A.M.; Critical Review – B.A.Ş., A.M.

Acknowledgments: This study was funded by Scientific Research Projects Coordination Unit of Istanbul University-Cerrahpaşa. Project Number: SBA-2017-25307

Declaration of Interests: There is no conflict to declare.

Funding: This study was funded by Scientific Research Projects Coordination Unit of Istanbul University-Cerrahpaşa. Project Number: 25307.

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